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THE REAL TEMPERATURES THROUGHOUT NORTH AND SOUTH AMERICA

By MARK JEFFERSON

What a suggestion of burning heat has the phrase "torrid zone" and how unwarranted! And how pleasing is the name "temperate" applied to our own zone! Well do we know the fierce heat of our summer hot spells, the bitter cold of our winter cold waves; well have we in mind the sudden rises and yet more sudden drops that characterize the temperatures in this zone that is temperate in name but so intemperate in fact that the only sound description of it that applies at all times is that every season is exceptional: the summer is the hottest or the coolest, the driest or the wettest, the winter is the mildest or the most severe in the memory of the oldest inhabitant!

TROPICAL UNIFORMITY VS. TEMPERATE CHANGEABILITY

The present collection of diagrams attempts to set forth the facts of the actual temperatures in all America, almost from the Arctic to the Antarctic (Fig. 1), by showing the afternoon heat and the nightly cooling day by day throughout the hottest month and the coolest month of a whole year. For a good many places the year is 1904.

On examining these diagrams we shall see that regularity, monotonous recurrence of a fairly constant change from warm days to less warm nights, is the characteristic of tropical temperatures, and that changeability, incessant alternation of stimulating spells of heat and cold, characterize our temperate zone. It is not true that our weather is more temperate than tropical weather. It is not true that the equator is the hot belt of the earth. It is not true that the temperature régime of all the zones may be found in the torrid zone on ascending from the lowlands to the lofty mountain heights. Our weather is intemperately changeable. The world's greatest heats are encountered along the borderland between temperate and torrid zones. Each level in the mountains of the torrid zone is characterized by monotonous repetition of one set of temperature oscillations—among lower and lower temperatures at higher and higher altitudes, it is true, but quite without the sudden changes or even the contrasts between summer and winter temperatures that mark the temperate and polar zones. The night is the winter of the tropics, recurring with very little difference 365 days in a year, whether it be from days between 75° and 90° to nights between 60° and 75° beside the Gulf of Mexico at Havana, or days between 20° and 30° and nights between 7° and 20° at the summit of El Misti, 19,000 feet above the waters of the Pacific, near Arequipa, Peru.

Attention was called in the pages of this publication[1] several years ago

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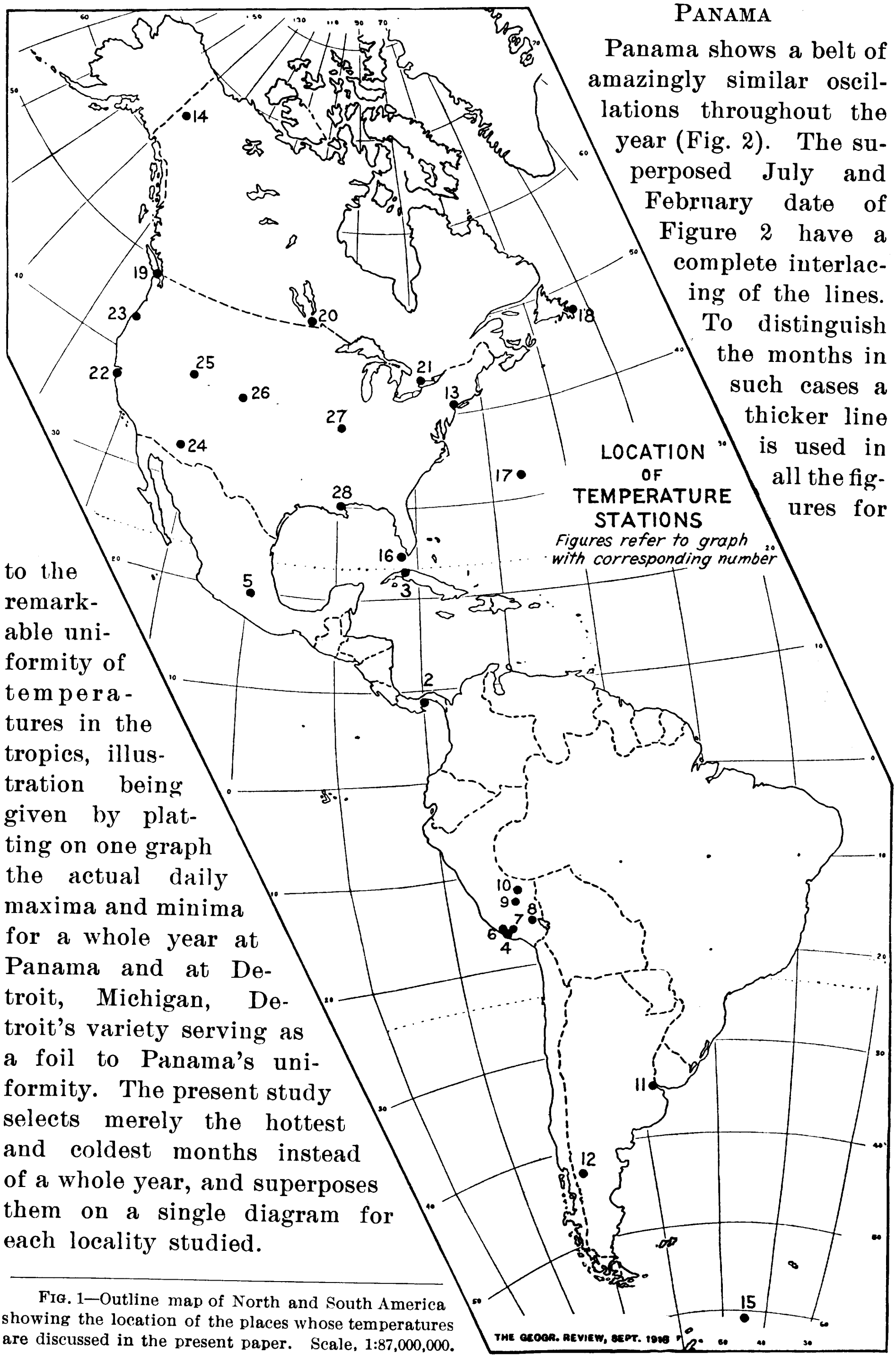
[1] Mark Jefferson: The Steady Warmth of the Tropics, *Bull. Amer. Geogr. Soc.*, Vol. 47, 1915, pp. 346-348.

PANAMA

Panama shows a belt of amazingly similar oscillations throughout the year (Fig. 2). The superposed July and February date of Figure 2 have a complete interlacing of the lines. To distinguish the months in such cases a thicker line is used in all the figures for to the remarkable uniformity of temperatures in the tropics, illustration being given by platting on one graph the actual daily maxima and minima for a whole year at Panama and at Detroit, Michigan, Detroit's variety serving as a foil to Panama's uniformity. The present study selects merely the hottest and coldest months instead of a whole year, and superposes them on a single diagram for each locality studied.


LOCATION OF TEMPERATURE STATIONS
Figures refer to graph with corresponding number
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THE GEOGR. REVIEW, SEPT. 1918

FIG. 1—Outline map of North and South America showing the location of the places whose temperatures are discussed in the present paper. Scale, 1:87,000,000.

the warmer month. The February mean temperature at Panama is 80.8°, that of July 81.1°. So far as temperatures by the thermometer are concerned one cannot tell the hottest month of the year from the coldest, though as July is a month of the rainy season the humidity doubtless makes the *sensible* temperature—with which we are not here concerned—much hotter. But one swallow does not make a summer, and Panama may not be perfectly typical of tropical lowlands. What are the facts for Havana, for instance?

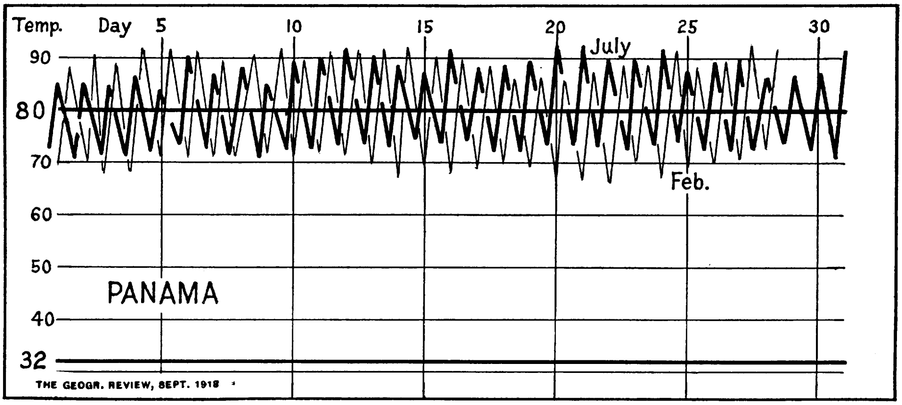

FIG. 2—Daily maximum and minimum temperatures at Panama in July and February, 1913.
July: mean 81.1°; range 16°; variability 1.2°; rainfall 4.85 ins.
February: " 80.8°; " 19°; " 1.7°; " 0.22 ins.

Throughout the graphs, Figs. 2-28, the heavier curve represents the warmer, the lighter the colder month. The upper points of the curves represent the day-time, the lower points the night-time temperatures. The mean temperature of each of the two months shown is indicated by a broken horizontal line (not shown on this graph). The 80° and 32° lines are emphasized as representing the lower and upper limits respectively of temperatures termed in this paper *hot* and *cold*.

HAVANA

August is the hottest month and January the coldest (Fig. 3). There is still a great deal of steadiness, especially in the hotter weather. Havana is about 23° north of the equator, over twice as far as is Panama. The summer sun is well-nigh overhead, while in January it is halfway down to the southern horizon. January is distinctly cooler than August, in the mean 13° cooler. In actuality August afternoons range from 87° to 92°, and January ones from 69° to 82°. The nights in August range from 69° to 76°, in January from 52° to 65°. August is easily distinguished from January by greater warmth and much greater steadiness of temperature, though the irregularities of winter are not strong enough to make much difference. The nearest approach to a "spell of weather" is the last seven days of the month, with nights at 66° and days about 81°.

Two dark lines drawn on all these diagrams at 80° and 32° serve to compare temperatures from place to place. Arbitrarily it is proposed to call temperatures above 80° *hot* and those below 32° *cold*. This will give us a precise phraseology that is very convenient and not wholly without reason.

If we care to discriminate further we may call it *cool* between 50° and 32°, *mild* between 68° and 50°, and *warm* between 80° and 68°.

Accordingly, in August, days in Havana are hot and nights warm; February nights are mild and days warm. In Panama, on the other hand, days are hot and nights warm at all seasons. It is especially interesting to note that days in the high 90's and 100's with nights in the 80's, as in Chicago, July, 1916, occur only in the temperate zone. In the tropics they are unknown.[2]

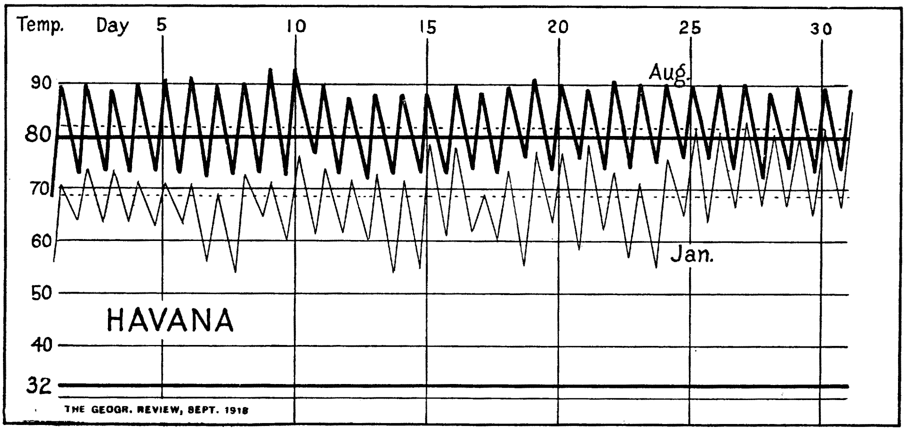

FIG. 3 (year: 1902).

August:	mean 81.8°;	range 16.4°;	variability 0.9°
January:	" 68.2°;	" 14.2°;	" 2.8°

MOLLENDO

A third tropical locality, close to sea level, like the first two, is Mollendo, 17° south of the equator on the Peruvian coast (Fig. 4). Mollendo shows the same tropical type of weather. February is the hottest month. as we are now south of the equator, and July one of the coolest. But Mollendo differs from both of our previous tropical examples in having no hot days. Warm days and nights are characteristic of February, mild days and nights prevail in July. Both Panama and Havana stand beside seas whose surface waters have a temperature of 80°, Mollendo beside waters at about 70°.

VARIABILITY AS A CRITICAL FACTOR

The reader should not miss the note of actuality in these diagrams. He reads instantly here the highest afternoon temperature that occurred in the year indicated on any and every day of the hottest month and of the coolest month. On the 9th or the 17th, or whatever day you will, the thermometer went so high or fell so low. The mind imagines the clothing suitable for street wear, what bedding would be agreeable at night. Average temperatures can never serve as a basis for such ideas. Yet a use may be made of averages to get a measure of the variability, which, it should be emphasized, is characteristically low in the tropics and high with us. For this purpose the average temperature of the whole day, roughly expressed by the half-sum of the day's maximum and minimum temperatures, is compared with the mean temperature of the whole month, as derived from the sum of all the maxima and minima divided by twice the number of days in the month. At Panama no day of either month shown has a mean temperature that differs more than 3° from the mean of the month. The average difference of all the July days from the mean is 1.2°; of the February days 1.7°. For Havana the mean variations of daily and monthly means are 0.9° for August and 2.8° for January. No single day of August at Havana varies more than 3° from the mean of the month. The more variable January, however, has nine days each of which is more than 5° warmer or cooler than the monthly mean. Mollendo has a mean variability of 1° in both February and July; neither month has a single day of mean temperature 5° different from the mean of the month.[3]

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[2] The nearest approach to this condition is in dry continental interiors: e. g. Fort Archambault (Shari River, central Africa, lat. 9° N.) had in April a mean maximum of 100° and a mean minimum of 75.4°; Daly Waters (northern Australia, lat. 16½° S.) in January, 1912, a mean maximum of 102.7° and a mean minimum of 76°.

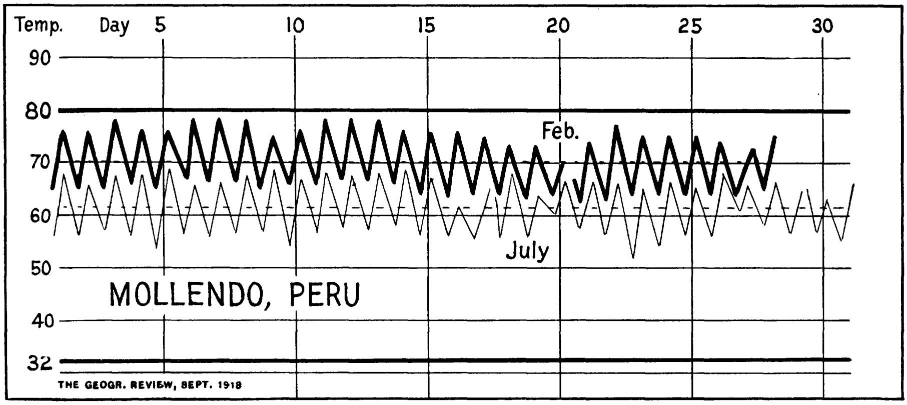

Fig. 4 (year: 1895)

February: mean 70.3°; range 11.0°; variability 1°
July: " 61.6°; " 10.4°; " 1°

Toluca, Mexico

In tropical America great human interest attaches to the highlands on account of the long-continued occupation of the lofty Mexican and Andean plateaus by native races who had attained the highest culture of all American peoples. Figure 5 gives the graph for Toluca, capital of the State of Mexico, 40 miles west-southwest of Mexico City, for December, 1902, and April, 1903. Ordinarily May is one degree warmer than April, but it was not so in 1903. Toluca, in latitude 19.3° N., is well within the tropics and 8,810 feet above the sea. Its temperature shows the same tropical steadiness as the three previous graphs. Expressed quantitatively, the mean variability of temperature for April is 2.5°, for December 1.8°. April had one day differing 10° from the mean and four differing from it by more than 5°. December has a single day differing more than 5° from the mean. Further, Toluca had no *hot* day and no *cold* day. Warm days with nights mild to cool characterize April, and mild days with cool nights December.

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[3] This variation of the mean of the days from the mean of the month must not be confused with the daily range of temperature—the difference between the maximum and minimum for the day. The variability may be very small indeed while the daily range of temperature is very large. For that it is only necessary that the same large daily oscillation of temperature be repeated with great steadiness day after day. The cooler month at Arequipa on Fig. 7 is a good example of great daily range and small variability. It should also be remarked that this expression of variation is not the same as that ordinarily described by the meteorological term "mean diurnal variability," which is the average of the temperature differences between successive days.

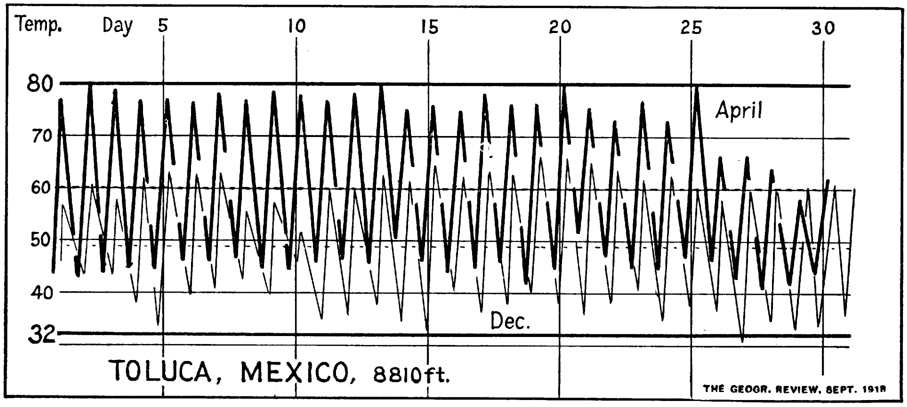

Fig. 5 (year: April, 1903, and December, 1902)
April: mean 60.0°; range 30°; variability 2.5°: rainfall 0.70 ins.
December: " 49.5°; " 23°; " 1.8°; " 0.53 ins.

Maintenance in the Tropics of Uniformity of Régime with Increasing Altitude

These are the most temperate temperatures in the world. It is to be noticed that the only change that has accompanied the elevation nearly two miles into the air is a change of the *pitch,* so to say, at which the temperature scheme is developed. We have got no winter by going up from sea level, but merely the same steady tropical oscillation among cooler temperatures. There is still the same monotonous daily swinging of the thermometer between limiting values that are almost fixed. We shall see below that real winter consists not merely of cold weather, but of cold weather strongly differing from a season of summer and highly variable in itself. A wire bent into the shape of the Panama graphs and laid along the 80° line of our temperature frame represents the temperatures of tropical lowlands. To represent the facts for various heights in the tropics, we have only to place the wire at lower levels on the diagram.

The increase in the daily range of temperature is local and not dependent on the height alone. More will be said of that later. But no position of such a wire can correspond to real winter.

PERUVIAN HIGHLAND STATIONS

We are fortunate to have means of illustration in the admirable work of the Peruvian Expedition of Harvard University.[4] A series of seven stations that will serve our purpose is found there. The observations were made for a very brief time, rarely much more than a year or two, by volunteer observers, but they are of the greatest interest because of their location.

	Elevation	*Latitude*	*Longitude*
Mollendo	Sea level	17.1° S.,	72° W.
La Joya	4,140 feet	16.8° S.,	72.2° W.
Arequipa	7,550 feet	16.4° S.,	73.1° W.
Vincocaya	14,360 feet	15.7° S.,	71.2° W.
Cuzco	11,100 feet	13.5° S.,	72° W.
Santa Ana	3,400 feet	12.5° S.,	73.2° W.

La Joya and Arequipa are on the western slopes of the Andes, Vincocaya on the summit of the Andean plateau, the ancient city of Cuzco in a sheltered valley sunk in the plateau, and Santa Ana "well beyond the eastern Cordillera near the limits of civilization; the valley is broad and bounded on the east and west especially by hills of moderate elevation."[5]

LA JOYA

In Mexico the hot month was 11° warmer in the mean than the cold one. At La Joya (Fig. 6) the warm month is but 8.5° warmer than the cold

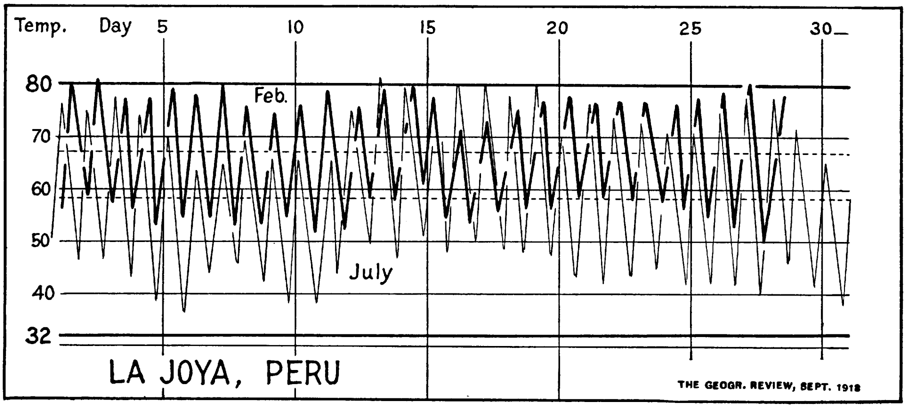

FIG. 6 (year: 1894)

February: mean 67°; range 22°; variability 1.4°: cloudy days 22
July: " 58°; " 28°; " 3.3°; " " 9

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[4] S. I. Bailey: Peruvian Meteorology, *Annals Astron. Observ. of Harvard College*, Vols. 39 and 49, Cambridge, Mass., 1899 and 1906; 1907 and 1908.

[5] *Ibid.*, Vol. 39, Part II, p. 162.

one. The striking feature of temperature here is that the daytime heats are so little different in the hottest and the coldest months, while the July nights are fully 10° colder than those of February. The range of temperature in the colder month was much greater, 28° in mild July and 22° in warm February. This difference was due to clouds. There were 21 or 22 cloudy days in February and but 7 or 8 in July. Both months had warm afternoons; but in February the nights were all mild, in July all cool. The mean variation of February days from the average temperature of the month was 1.4°, of July days 3.3°. No February day had a mean differing so much as 5° from the monthly mean. July had one day that differed by 10° and ten that differed by more than 5°. Like Toluca, La Joya had no hot temperatures nor cold ones, though it is little more than half as high above sea level.

Arequipa

Arequipa (Fig. 7) is nearly as high above the sea as the Mexican city, and its temperatures are very similar. In Arequipa it gets neither hot nor cold. Its temperature régime is strictly tropical, no day varying by 5° from the monthly mean; and the average variabilities of the warm and cold months are 0.8° and 1.8° respectively. Toluca had 2.5° and 1.8°. The mean temperatures of Arequipa's two months are 62° and 53.5°. Toluca had 60° and 49.5°. Arequipa's hottest temperature was 77° and its coldest 30°. Toluca had 80° and 31°. The daily range of temperature at Arequipa is 23° and 36°. Toluca had 30° and 23°. Still more exactly than at La Joya the afternoons at Arequipa reach about the same temperatures in the hottest and coldest months, but the nights of the cold month run much colder than the nights of the warm month. Warm days and mild nights characterize

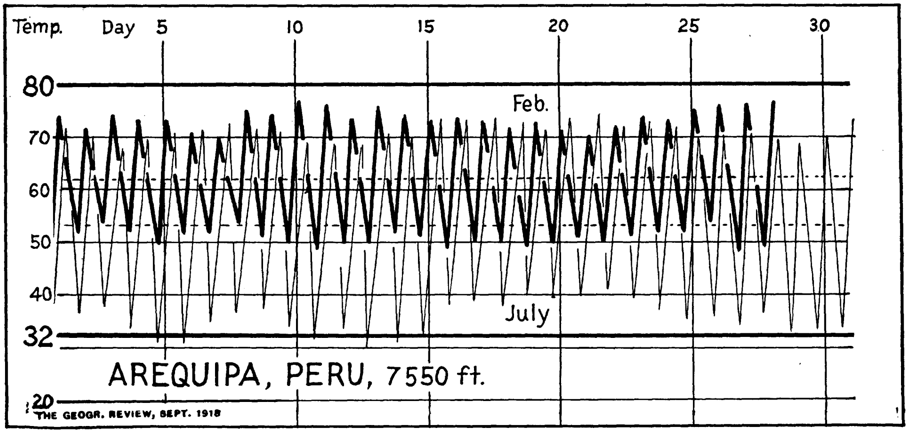

FIG. 7 (year: 1889)

February: 62.2°; range 23°; variability 0.8°; rainfall 0.08 in.
July: 53.5°; " 36°; " 1.8°; " 0.00

the warmer weather, and warm days and cool nights the coolest. There is nothing of winter in all this. The rainfall of February was 0.08 inch. In July there was none at all. The cloudiness of both months was reported a little over 5 on a scale of 10 for the year 1889, but for the four years 1892-95 the cloudiness averaged about 5 in February and in July 2.7, the daytime clouds cutting down the February maxima.

VINCOCAYA

Vincocaya is on the great shivering Andean tableland, at 14,360 feet above the level of the sea. The régime is still tropical (Fig. 8). November is now the warm month, averaging 4° warmer than any other. June was reported 0.2° cooler for the year 1889, but July may serve us, as we have its data. All the characters first described for Arequipa are seen again here. November days are mild, and the nights cool. July days are mild, and the nights cold. But this is not winter. The temperature is rarely above 60°. In the shade one is cold at all hours and at all seasons, but it is a continuous cold, unchanging from month to month. The range of temperature in the cooler month is now tremendous. One day starts in early with temperature below zero and by afternoon it has reached 52°, to fall below zero again by next morning. Truly the night is the winter of the tropics. Where these lines are being written, in Michigan, the temperature is falling below zero every night, but it has not been up to 50° in months, an excursion that the thermometer at Vincocaya makes in a few

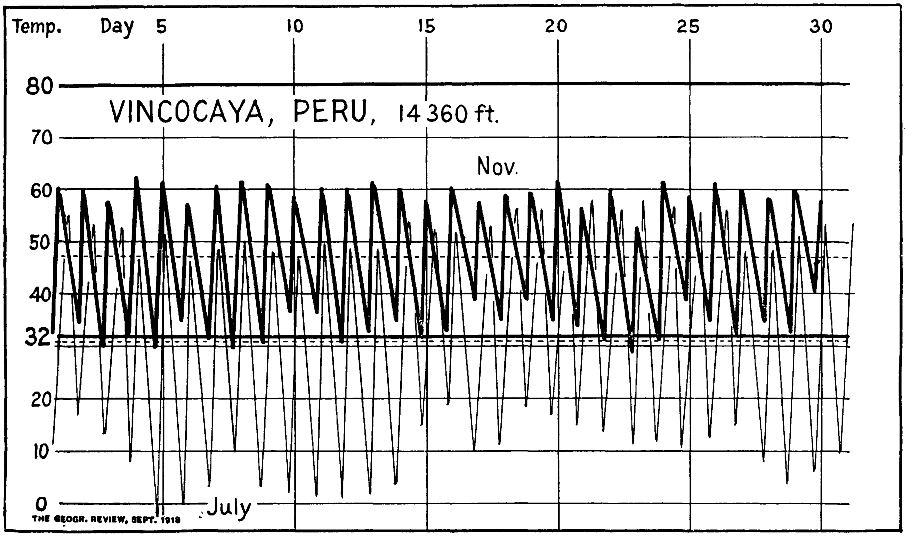

Fig. 8 (year: 1889)

November: mean 47°; range 26°; variability 1.3°; rainfall 0.54 in.
July: " 31°; " 43°; " 3.7°; " 0.00

hours. Its range is 26° in November, in July 43°.[6] There was .54 inch of rain in November, none in July. The average variation of the daily mean from the mean of the month was 1.3° in November, in July 3.7°—the greatest variability we have yet observed, as the diagram suggests. November had one day differing by 5° from the mean, and July had ten.

Cuzco

Now we descend from the wind-swept *páramos* of Vincocaya to the ancient Inca city of Cuzco, sunk in its sheltered valley 3,000 feet below.

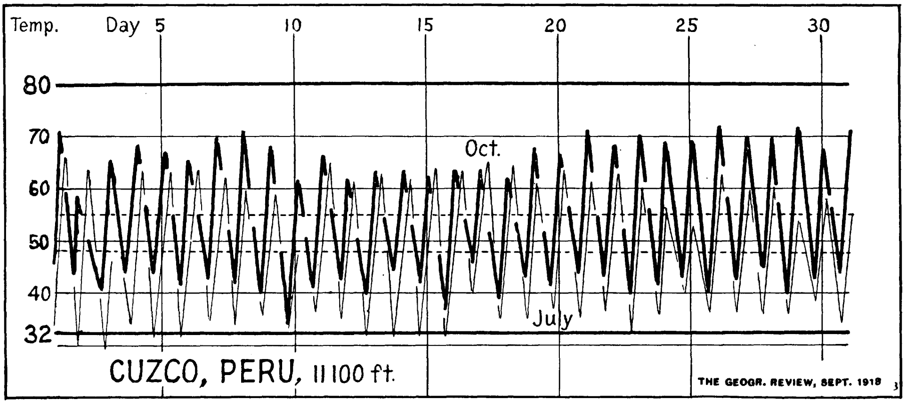

Fig. 9 (year: 1895)

October: mean 55°; range 25°; variability 1.9°; rainfall 4.58 ins.
July: " 48°; " 27°; " 1.0°; " 0.29 ins.

Although half a mile higher in the air than Toluca we are close to Mexican temperatures (Fig. 9).

	Toluca		*Cuzco*	
Mean temperature	April	60°	October	54.5°
	December	49.5°	July	48°
Daily range	April	30°	October	25°
	December	23°	July	27°
Variability	April	2.5°	October	1.9°
	December	1.8°	July	1°

Mild days and cool nights all the year, as in Toluca's cooler month, merely mark Cuzco as cooler than Toluca. Cuzco has 4.6 inches of rain in October with but 0.3 inch in July. The temperatures are still tropically steady. October has a single day varying over 5° from the mean of the month. July has no day that varies more than 3°.

Santa Ana

Now we pass the Andes and examine the temperatures at the ranch Santa Ana among the eastern foothills at the edge of the great Amazonian lowland (Fig. 10). Our crooked wire is lifted to the 80° line, for we are now little more than half a mile above sea level. Both November and July have hot days and cool nights. November averages 75.5°, and July 70° with daily ranges of 24° and 29°. The average variation for both months is 3.3°, if the record is trustworthy. November has one day varying over 10° from the mean, and six days over 5°. July has eight days differing more than 5°.

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[6] For similar examples in other stations of the Peruvian Andes see the graphs of diurnal range of Morococha (14,300 feet) and Santa Lucia (15,500 feet) in Isaiah Bowman: The Andes of Southern Peru, New York, 1916, pp. 172 and 162.

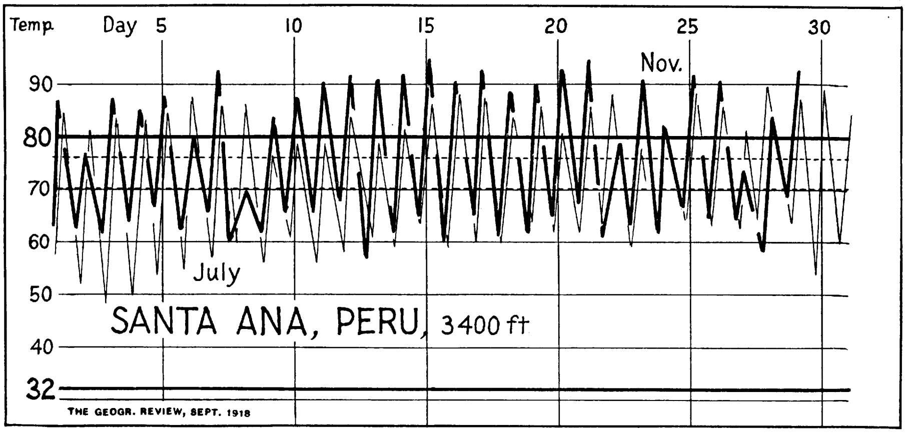

FIG. 10 (year: 1894)

November: mean 76°; range 24°; variability 3.3°; rainfall 1.45 ins.
July: " 70°; " 29°; " 3.3°; " 0.00

VARIABILITY AS THE DISTINGUISHING FACTOR BETWEEN TROPICAL AND TEMPERATE RÉGIMES

To say the night is the winter of the tropics is to say they have no winter. We have seen the extraordinarily temperate character of the tropical warmth. As far as heat changes are concerned the tropics are the truly temperate regions of the earth. In the tropics the variability of the daily temperature means from the means for their month is very low. The facts are gathered together in the following table.

	LATITUDE	ELEVATION IN 1,000 FT.	VARIABILITY *Hot month*	*Cold month*
Panama	9° N.	0	1.2°	1.7°
Havana	23° N.	0	0.9°	2.8°
Mollendo	17° S.	0	1.0°	1.0°
Toluca	19° N.	8	2.5°	1.8°
La Joya	17° S.	4	1.4°	3.3°
Arequipa	16° S.	8	0.8°	1.8°
Vincocaya	16° S.	14	1.7°	3.7°
Cuzco	14° S.	11	1.9°	1.0°
Santa Ana	12° S.	3	1.3°	1.3°

Roughly speaking, tropical days may vary about 1½° from the mean of the month in the warm season and in the cool season. The only weather at all like this beyond the tropics is on oceanic islands, where we shall find such equivalent values as 1.3° in the warm weather and 5.6° in the cold, a similarity for the warm season only, cool weather having a variability twice as great. But typical continental places in the temperate zones have variabilities in the warm and cool weather respectively of 3.7° and 6.9°. This is indeed their most striking characteristic as lands with winter, and the winters are particularly characterized by variability. As a certain element of vagueness always attaches to considerations of averages, it may make the matter somewhat clearer to say that out of the nine warm and nine cool months of tropical temperature considered here (a total of 552 days) just 3 days had a mean temperature that differed more than 10° from the mean temperature of their month, and only 47 days differed from the monthly mean by more than 5°. These 47 amount to less than 9 per cent of the total time. But of the 920 days of temperature here studied for the temperate zone 320, or 40 per cent, varied in their mean more than 5° from the mean of the month; 146 days, or 16 per cent, varied more than 10°; and 21 days, or over 2 per cent, more than 20°!

Dwellers in the tropics cannot find winter merely by climbing to mountain snows. They must pass out of the torrid zone into the extratropical regions. The temperature graphs that are encountered can no longer be represented even approximately by one bent wire placed at various temperatures on our diagram, but we need a new wire of very irregular shape, especially to represent the season of winter.

DIFFERENCES BETWEEN WARMEST AND COLDEST MONTHS, AND ABSOLUTE TEMPERATURE RANGE

It is of course also true that the difference is very slight between the warm and cold months in the tropics, as is shown in the little table here printed, the first column of whose figures gives the differences between the mean temperatures of the warm and cool months shown on the torrid

	Differences Between Means of Warmest and Coolest Months	*Absolute Range of Temperatures*
Panama	0.3°	27°
Havana	14°	40°
Mollendo	9°	29°
Toluca	10°	49°
La Joya	8.5°	52°
Arequipa	9°	47°
Vincocaya	16°	75°
Cuzco	7°	45°
Santa Ana	5°	49°
Average	9°	46°

zone diagrams. The mean of the nine values is about 9°. Now the mean difference of temperature of the seasons of the three islands or oceanic stations in the temperate zone discussed in this paper is 22°; for the sixteen continental points in the temperate zone, 38°. Yet more striking are the contrasts between the actual highest and lowest temperatures reached in the torrid and temperate zones. This is given in the second column of figures. The corresponding absolute ranges at temperate zone places attain 120°, 126°, and 129°. The least differences found among the places studied in the temperate zone are 58° and 61°, and the average value is 93°! In other words the difference between mean warm and cold month temperatures is four times as great in the temperate zone as in the tropics, and the absolute range of temperatures twice as great. But for man it is pretty certain that the chief advantage of the temperate zone over the torrid lies in the stimulation resulting from its great daily variability.

Buenos Aires

Buenos Aires, a sea-level station not very far beyond the southern tropic, is a good example to begin with (Fig. 11). It shows new things in the way of variability of the daily mean. For the summer, February is the type month; for this month the variability is 6.1°, for July, the winter month, it is 5°, that is, twice as much as in the tropics. The eye is satisfied that the graph is of unusual crookedness in comparison with its predecessors. Here are our first "spells of weather," several days that run well below the mean temperature followed by several more running well above it. At Buenos Aires this appears to be most striking in summer, unlike most stations in the United States, where such periods are much stronger

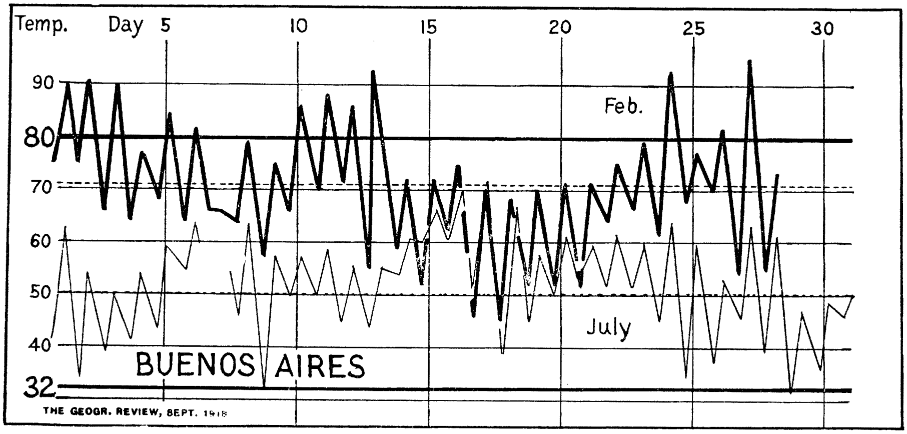

Fig. 11 (year: 1904)

February: mean 71°; range 18°; variability 6.1°; rainfall 2.16 ins.
July: " 50°; " 10°; " 5.0°; " 2.48 ins.

in winter. On one summer day a heat of 95° was reached, as great as any day we had record of at Santa Ana and greater than Havana or Panama during the year of our record. The winter temperature, however, twice touched freezing. February and July each had four days whose mean temperature differed more than 10° from the mean of the month and sixteen that differed more than 5°. But although characteristic in this element of changeableness, the winter of Buenos Aires is not cold. On the 17th the winter day happened to be warmer than the summer one. A winter warm spell may easily be as warm as a summer cool one; but there is no uniformity, no recurring of identical temperature oscillations. The summer is often warm, as often hot. The winter is mild or cool.

COLONIA 16 DE OCTUBRE

A most interesting record is that of Colonia 16 de Octubre in the southwest Argentine (Fig. 12). It lies in a foothill valley of the Patagonian Andes, in 43° S., 600 miles farther south than Buenos Aires. It is of course colder than Buenos Aires, 12° colder in the mean of the year. The coldest month is 24° colder than the hot month, against a similar difference of 20° for Buenos Aires. The summer days are warm, occasionally hot, and the nights usually cool. In winter the days are cool, the nights cold. The daily range of temperature is strikingly great, 25° and 15°, while Buenos Aires has but 18° in both months. The smaller range of July is doubtless

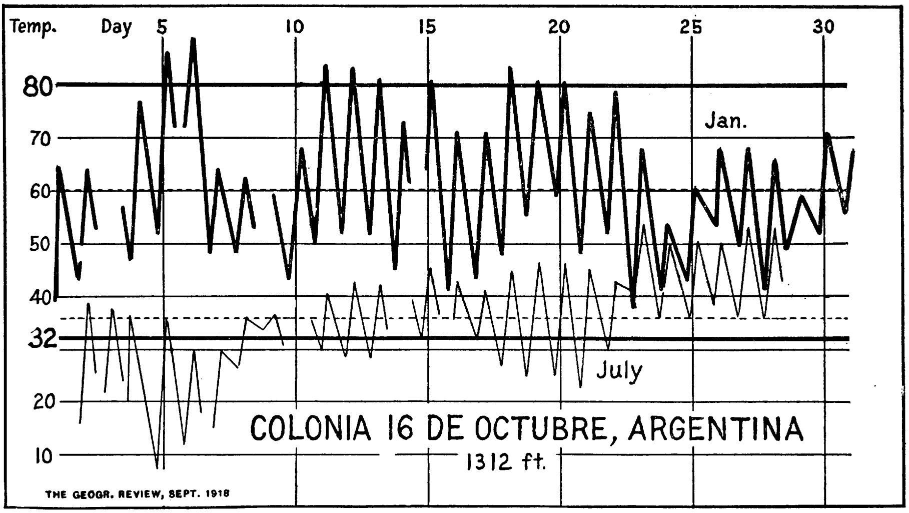

FIG. 12 (year: 1905)

January:	mean 60°;	range 25°;	variability 5.3°;	rainfall 0.52 in.
July:	" 36°;	" 15°;	" 4.8°;	" 2.70 ins.

due to clouds, as 2.7 inches of rain falls in that month against 0.52 in January. In the means the variability is a little less than at Buenos Aires, in January 5.3° and July 4.8°. Individual days, if allowance is made for missing observations, differ from the mean almost exactly as at Buenos Aires. This is rather surprising inasmuch as Buenos Aires is so much nearer the southern tropic than Colonia 16 de Octubre. Probably the narrowness of the southern continent in these latitudes prevents the development of distinct spells of weather.

New York

From the southern temperate zone we may well turn to the northern. New York is a lowland station like Buenos Aires, but it is six degrees farther from the equator and North America is three times as wide in this latitude as South America in the latitude of Buenos Aires. The chief novelty shown on the diagram (Fig. 13) is the further separating of summer and winter. At New York summer is frankly warm and winter cold. But the summer is much less variable than the winter. The highest temperature at New York was 93°, the coldest 4° below zero. At Buenos Aires the corresponding figures were 95° and 32°. At New York the mean of the warmest month was almost 50° warmer than the mean of the coldest month, against 21° at Buenos Aires. The chief meaning of this is that

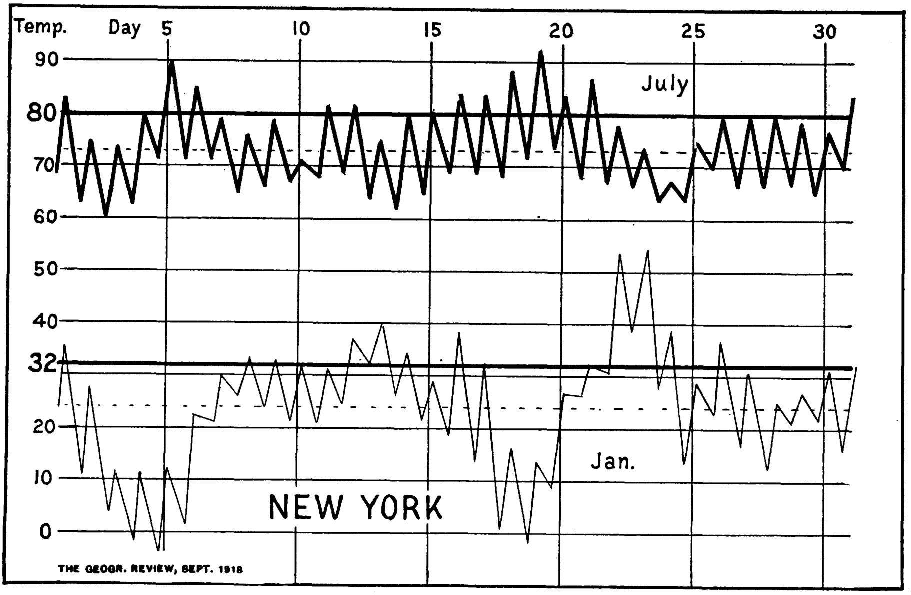

Fig. 13 (year: 1904)

July: mean 73.5°; range 13°; variability 3.0°; rainfall 4.4 ins.
January: " 24.0°; " 12°; " 9.3°; " 3.4 ins.

the New York winter is really cold. But at New York the variability is 9.3°, exceeding Buenos Aires in this element almost as much as Buenos Aires outdid the tropical stations. That any day in the month may be 9.3 degrees warmer or colder than the mean of the month signifies very perceptible temperature fluctuations. To go a little into detail, New York in the winter of 1904 had three days of variability greater than 20° and eleven of more than 10°. A glance at the graph shows two very pronounced cold spells of from three to four days duration each, and two principal warm spells of from nine to twelve days.

DAWSON CITY

The most northerly station for which data are at hand is Dawson City in the Yukon, near the Arctic Circle (Fig. 14). The situation is continental, walled off from the Pacific by the lofty Alaskan ranges. Summer days are warm, and nights are mild or cool; but the winter is bitterly cold, night and day. There were only two days in January, 1908, when the thermometer rose as high as 30° in the afternoon to fall back to 15° below at

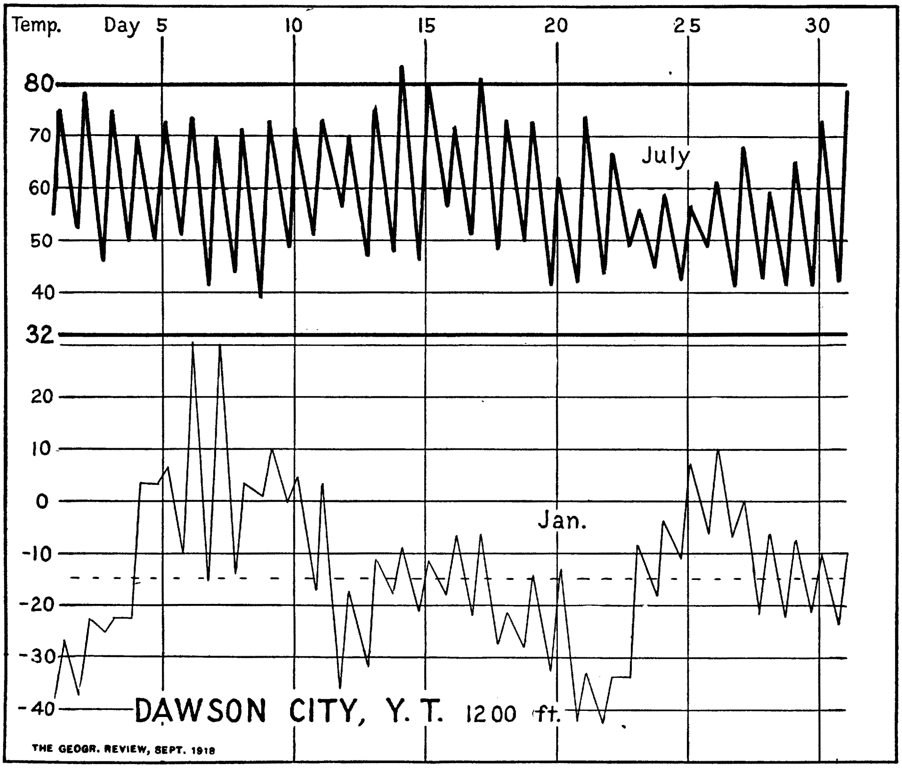

FIG. 14 (year: 1908)

July:	mean 60.0°;	range 24°;	variability 4
January:	" −14.5°;	" 15°;	" 10

night. The thermometer stayed below zero all the month except for parts of ten days. The average variability of Dawson days is a little greater than at New York, 4° in July and 10° in January. July had one day the mean of which differed from the mean of the month by 10°. January had five that differed more than 20° from the mean, and thirteen differing more than 10°. The graph illustrates the control of winter temperature changes by spells of weather, even more plainly than at New York. The summer at Dawson City is not strikingly variable. Dawson has the extreme continental type of temperature régime, with 75° difference between the means of the hottest and coldest months, and an absolute range of 126°.

LAURIE ISLAND, SOUTH ORKNEYS

Almost as different from land temperatures in the temperate zone as these are from tropical temperatures, are the temperatures of islands in the temperate zone. For instance at Laurie Island, 300 miles south of Cape Horn in the South Atlantic Ocean, January, the summer month, is of the oceanic type (Fig. 15). The seagirt land holds as steadily at about 32° as if the sea were a great freezing mixture, thickly studded with floating lumps of ice. But the winter is of very severe character, with notable spells of weather. Always below the freezing point for salt water, it goes lower than —15° four times in the month, as if a frozen sea supplied a continental régime for the winter record. The mean variability of January

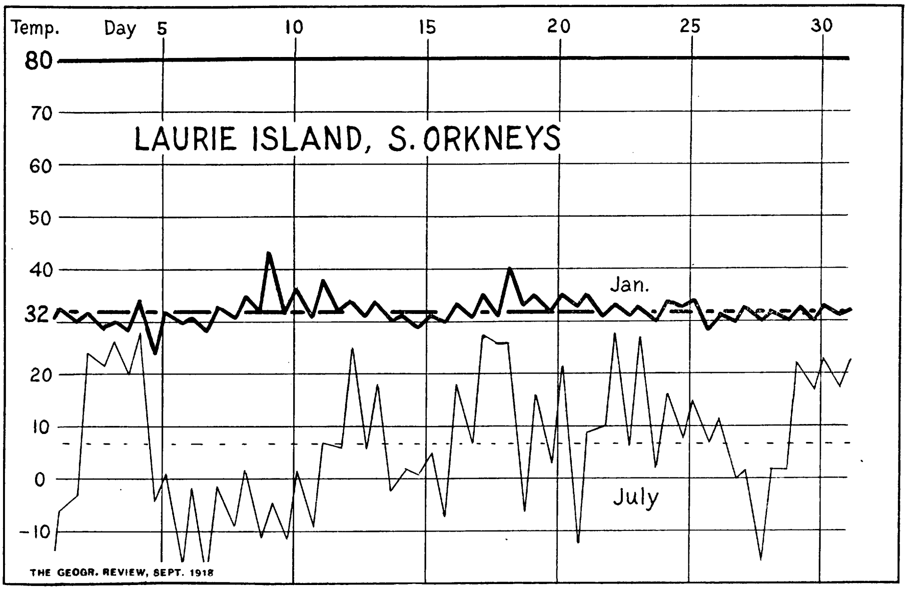

FIG. 15 (year: 1904)

January:	mean 32°;	range 3.5°;	variability 1.5°
July:	" 7°;	" 13.0°;	" 9.5°

days, 1.5°, is to be contrasted with 9.5° for July. Laurie Island is in latitude 61° S., and its winter is the nearest like that of Dawson City that we have yet discussed from the southern hemisphere.

KEY WEST

Another oceanic record is for the island of Key West (Fig. 16), off the tip of Florida in the Gulf of Mexico. Its tropical situation in 25° N. lifts the September temperatures to hot days and nights that are usually warm. September is the warmest month. Its variability is 1.2°. The winter, with warm days and mild nights, has fairly distinct spells of weather and a variability of 3.7°. Five days in February differed more

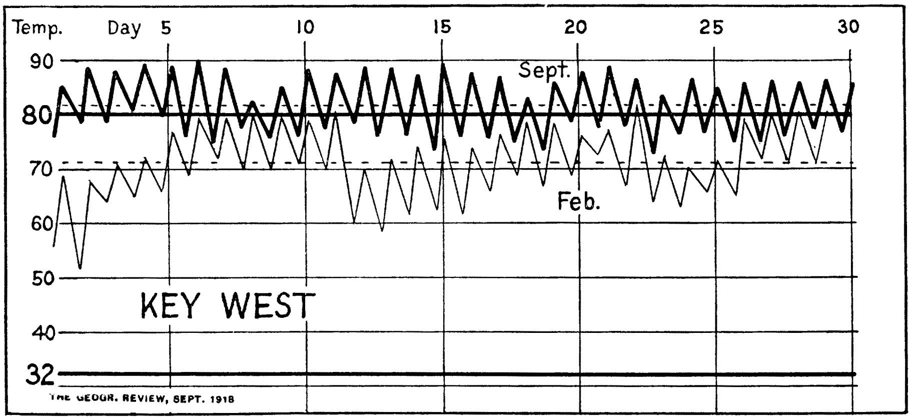

FIG. 16 (year: 1904)

September: mean 82°; range 10°; variability 1.2°; rainfall 3.6 ins.
February: " 71°; " 10°; " 3.7°; " 1.1 ins.

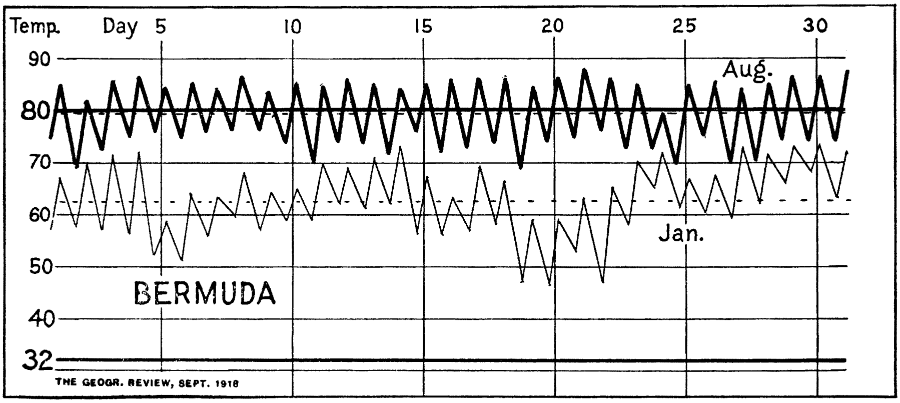

FIG. 17 (year: 1904)

August: mean 79.2°; range 10.0°; variability 1 2°
January: " 62.5°; " 11.5°; " 3.6°

than 5° from the mean of the month. One might be tempted to attribute the winter spells of weather to the adjacent continent of North America were it not that the Bermudas, 800 miles out in the Atlantic, show almost identical forms.

PROSPECT, BERMUDA

The summer of these oceanic islands inclines to the tropical. The Bermudas' hot month (Fig. 17) is almost identical with Havana's except for the greatly lessened daily range of temperature, 10° to Havana's 16°. The winter, too, has a smaller daily range and distinct spells of weather.

ST. JOHNS, NEWFOUNDLAND

St. Johns, Newfoundland, is thrust far out into the North Atlantic in latitude 48° N. July and February represent the hottest and coldest months of the year 1908 (Fig. 18). The thermometer went up once to 83° and once fell to —1°. In spite of oceanic surroundings the February temperatures averaged 27°. At mid-month a cold spell carried the temperature below 10° for four days running; then a warm spell sent it up for another three to the high forties. The summer variability of the daily mean averages nearly 5°, the winter one nearly 8°. There is no hot weather, only mild weather and warm for most of the summer, and cold or cool for most of the winter. February had ten days that varied more than 10° from the mean.

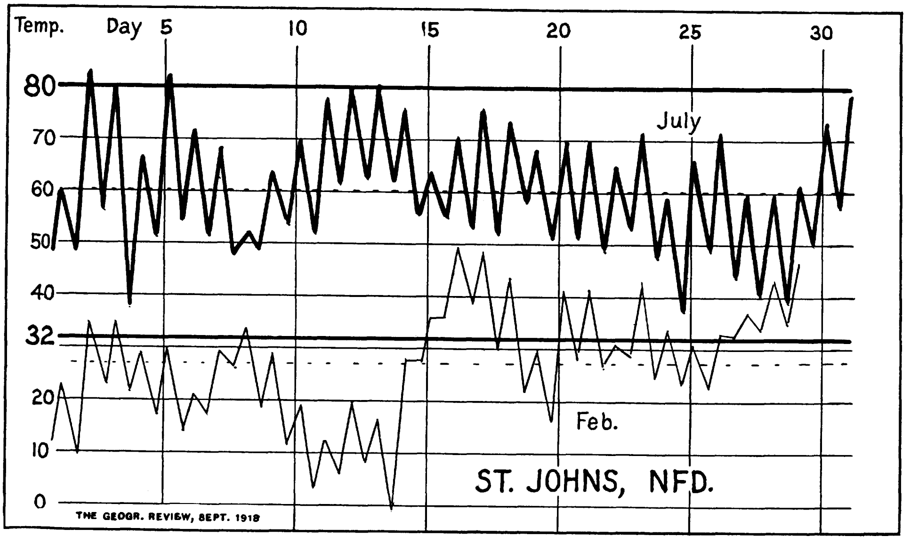

FIG. 18 (year: 1908)

July: mean 60.5°; range 19°; variability 4.8°; rainfall 2.70 ins.
February: " 27.0°; " 12°; " 7.8°; " 5.23 ins.

VICTORIA, B. C.

But what type of temperature will obtain at the western border of North America, where the prevailing winds blow from the Pacific? Victoria, B. C., gives the answer (Fig. 19). Apart from the daily range of temperature the summer and winter graphs are not very different in variability, 3.2° in warm weather and 3.8° in cool. The greater range of summer temperature is due to the dryness of that season and its clear skies. Less than half an inch of rain falls in July to nearly four inches in February. The winter is cool; the summer warm by day and mild by night. Most of the winter and part of the summer have the tropical steadiness of diurnal oscillation which were called oceanic for the Bermudas and Key West.

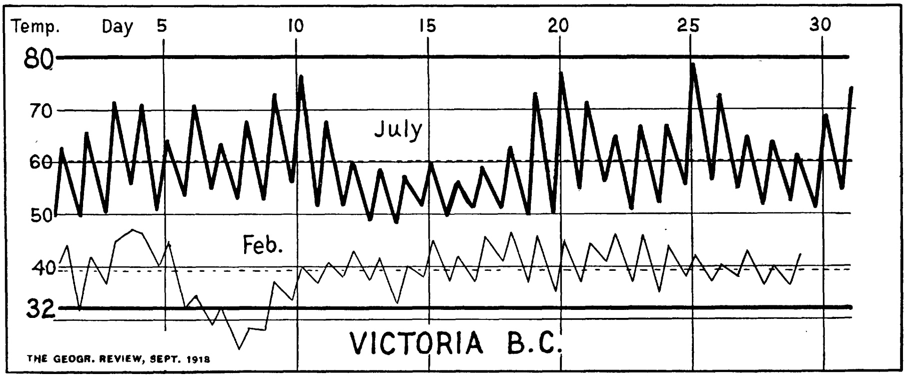

FIG. 19 (year: 1904)

July:	mean 60°;	range 14°;	variability 3.2°;	rainfall 0.48 ins.
February:	" 39°;	" 5°;	" 3.8°;	" 3.93 ins.

The Pacific coast stations are all bathed in ocean air and have oceanic types of temperature, especially in the greater mildness and steadiness of their winter. But Newfoundland, though far out in the Atlantic, is almost as much bathed in land air as New York because its winds are usually from the west; and so it has a continental temperature. Victoria, on the other hand, had but one day in its winter month that differed as much as 10° from the mean and but seven that differed more than 5°.

WINNIPEG

Winnipeg, in about the same latitude as Victoria and St. Johns, is in the heart of the continent. We should expect a strongly developed continental temperature régime there, and we are not disappointed (Fig. 20). The temperature goes up to 93° and down to —36°. Only four afternoons had temperatures above freezing. The winter cold spells are severe, the summer ones perceptible. In summer the days are warm, occasionally hot; the nights mostly mild. The variability has the largest value observed in this study, 5.6° in July and 11° in January. January had four days with a variation of more than 20° from the mean of the month.

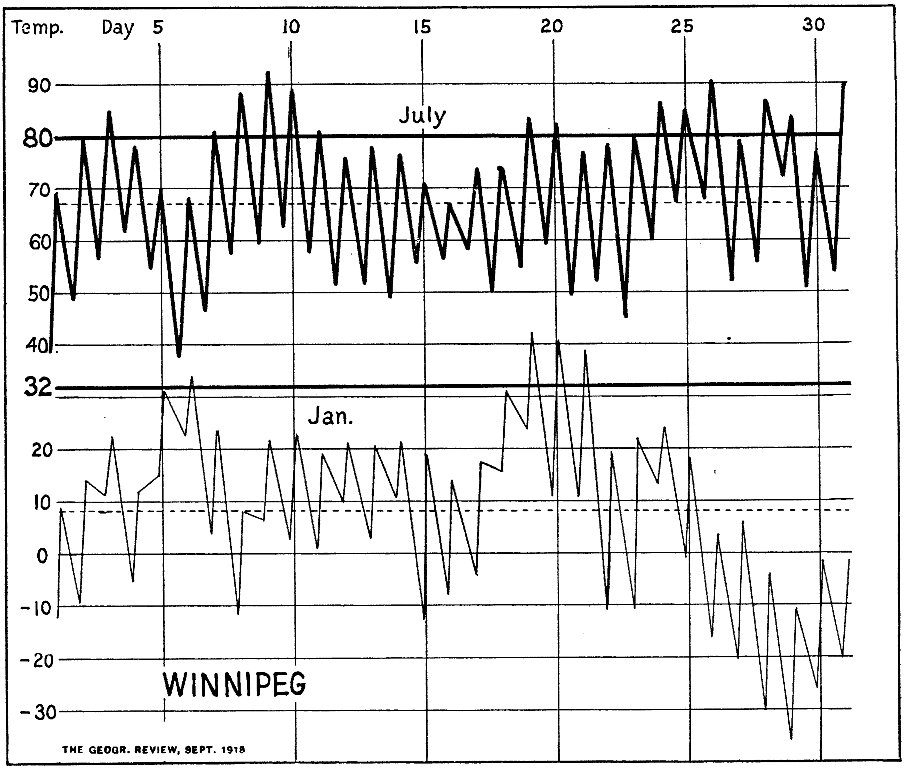

FIG. 20 (year: 1908)

July: mean 67°; range 26°; variability 5.6°; rainfall 1.76 ins.
January: " 8°; " 20°; " 11.2°; " 0.44 in.

TORONTO

February and July at Toronto (Fig. 21) do not differ much from the same months at Winnipeg, except for less severity of winter cold. Summer is warm to hot by day and mild to cool at night. The winter is cold. The variability is 3.5° and 8°, distinctly less than at Winnipeg. The case illustrates the practical working of variability. Winnipeg has a *mean* July temperature 4° cooler than Toronto; but, owing to its high variability, it saw the thermometer go up one day to 93° when at Toronto it was only 92°. Toronto lies five degrees farther south in latitude, and its temperature is doubtless influenced by the nearness to the waters of Lake Ontario.

SAN FRANCISCO

One of the most interesting temperatures studied is that of San Francisco (Fig. 22). The climate is of the mild, Pacific-coast type, milder even

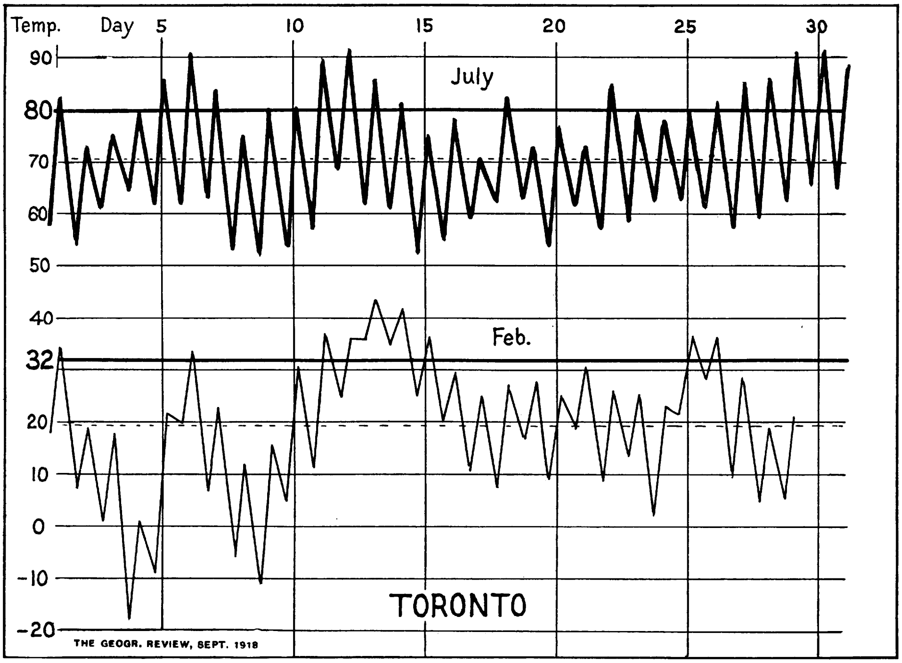

FIG. 21 (year: 1908)

July:	mean 71°;	range 22°;	variability 3.5°;	rainfall 2.97 ins.
February:	" 19°;	" 16°;	" 8.0°;	" 3.77 ins.

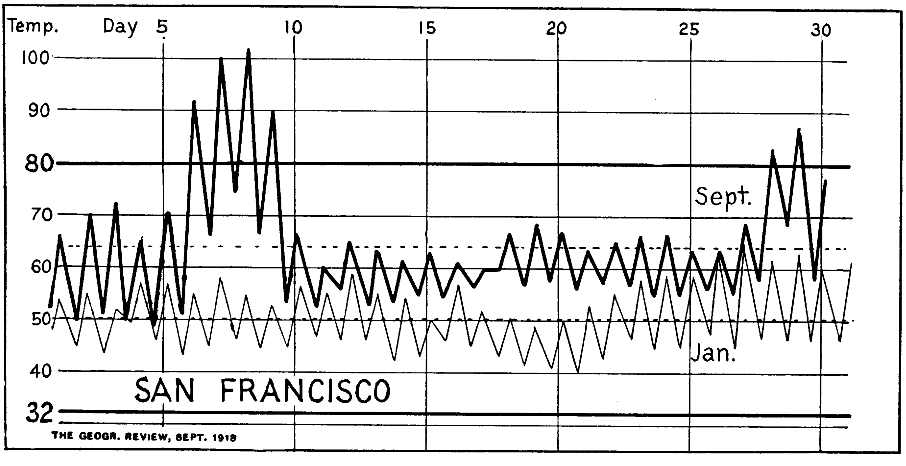

FIG. 22 (year: 1904)

September:	mean 64°;	range 14°;	variability 6.1°
January:	" 50°;	" 11°;	" 2.4°

than Victoria's. September, the hottest month, is barely 10° hotter than January, the coldest month. For the most part the temperature oscillates from day to night almost with the monotony of the tropics, or of islands in the sea, but the warm month has unique freaks of hot weather. Usually the hot spells of the temperate zone are balanced by ensuing cooler or cold ones. Not so the hot spells of September at San Francisco. They rise from the uniform 60° weather to the 80's, 90's, and sometimes 100's for a few days and then drop back again, to oscillate as before between 55° and 60°. There are no counterbalancing cold spells. These hot spells were unusually pronounced in 1904, but the year was not exceptional. The variability of September is of course increased by these hot spells. For a period of eight years it averaged 3.8°. Cold spells do not seem to occur at San Francisco, either in warm weather or cool, and the hot spells described are characteristic of warm weather only. In calling them unique I am comparing them only with other stations that were studied. They do not occur at Marshfield, Ore. (Fig. 23), or San Diego and Los Angeles, Cal. All of these have the even temperature of the oceanic climate, without these singular bursts of heat. They are not mentioned in McAdie's "Climatology of California."[7] To the east of the Coast Range, at Red Bluff, at Sacramento, and at Fresno, in the Great Valley of California the temperatures show the continental heat of summer and cold of winter, although the annual range of temperature is not great; but the daily range has become considerable, and spells of both hot and cold weather are evident in both seasons.

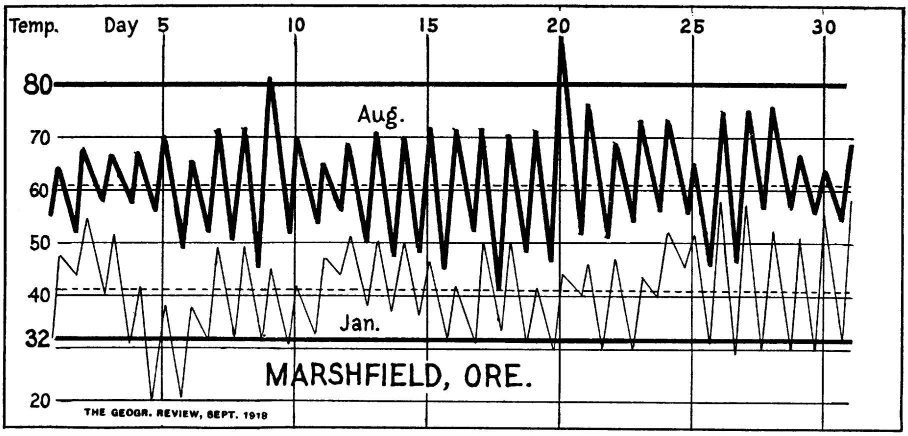

FIG. 23 (year: 1913)

August: mean 61°; range 20°; variability 2.0°; rainfall 0.15 ins.
January: " 41°; " 15°; " 3.8°; " 12.06 ins.

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[7] Alexander McAdie: Climatology of California, *Weather Bur. Bull. L.*, U. S. Dept. of Agriculture, Washington, D. C., 1903.

PHOENIX, ARIZ.

The temperature régime at Phoenix, Arizona (Fig. 24), is a rather moderate example of temperate zone weather. The variability is 2° and 4.6° in the warm and cold months, respectively. This is distinctly greater than in the tropics but small for the temperate zone. Owing to the aridity of the region its daily range of temperature is very large; but the special feature is great summer heat. It was above 100° on all but six days of July, 1904, and three times reached 110°. The winter was not extremely cold. Fourteen times in January it fell below freezing.

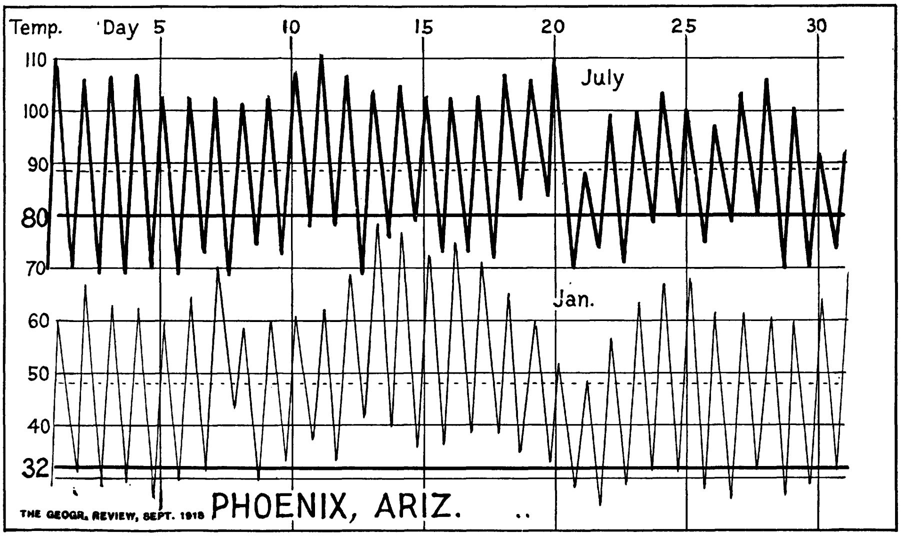

FIG. 24 (year: 1904)

July: mean 88°; range 29°; variability 2.0°; rainfall 0.65 in.
January: " 48°; " 32°; " 4.6°; " 0.26 in.

SALT LAKE CITY

At Salt Lake City (Fig. 25) with a variability of 3.8° and 5.4°, the daily range of temperature is large in summer but much less in the rainier winter. The summer is rather hot, and the winter distinctly cold. Salt Lake City forms a transition type between Phoenix and St. Louis and other places in our humid east.

DENVER

Denver (Fig. 26) has much greater variability, 4.4° and 7.3°, but its summers and winters are in other respects about what we should get if we cooled the Phoenix weather about 20°. It is six degrees farther north in latitude and less arid. It has a hot summer and a cold winter.

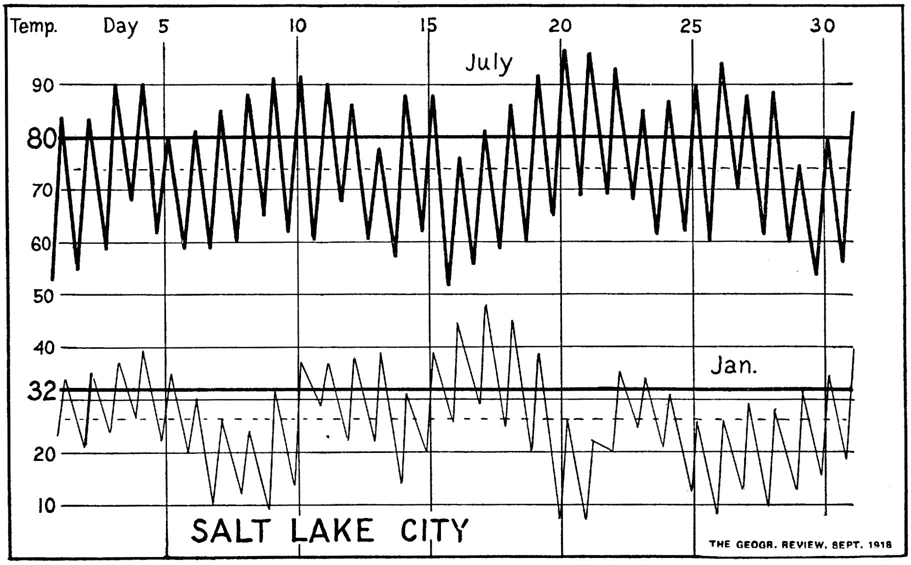

FIG. 25 (year: 1904)

July:	mean 74°;	range 26°;	variability 3.8°;	rainfall 0.65 in.
January:	" 26°;	" 16°;	" 5.4°;	" 1.45 ins.

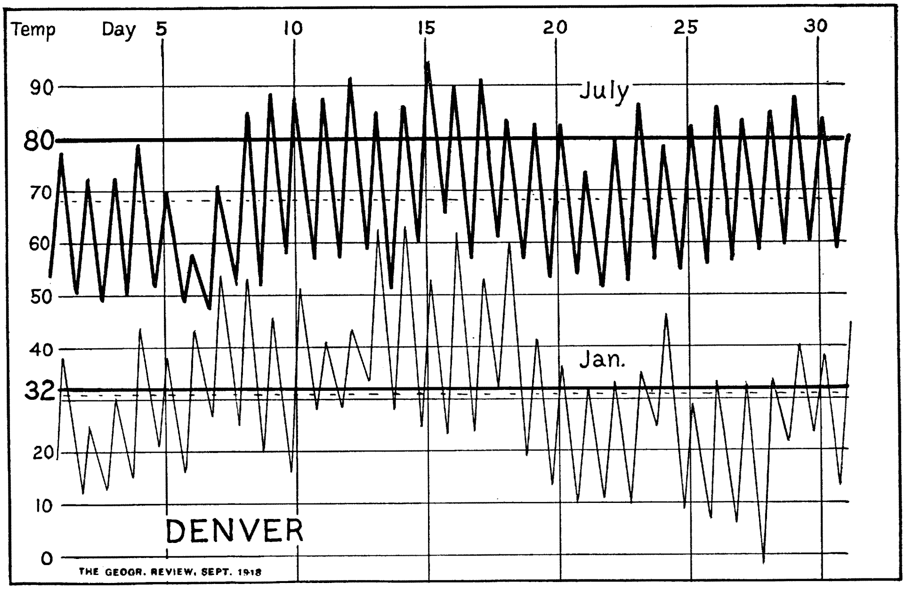

FIG. 26 (year: 1904)

July:	mean 68°;	range 27°;	variability 4.4°;	rainfall 1.6 ins.
January:	" 31°;	" 24°;	" 7.3°;	" 0.5 in.

St. Louis

In a general way the temperatures of St. Louis (Fig. 27) are about like those of Winnipeg, Toronto, Chicago, Detroit, and Cincinnati, and also St. Johns, Boston, and New York. Summer is hot, winter is cold, and variability is very great, especially in the cold season, with a figure of 10.4°.

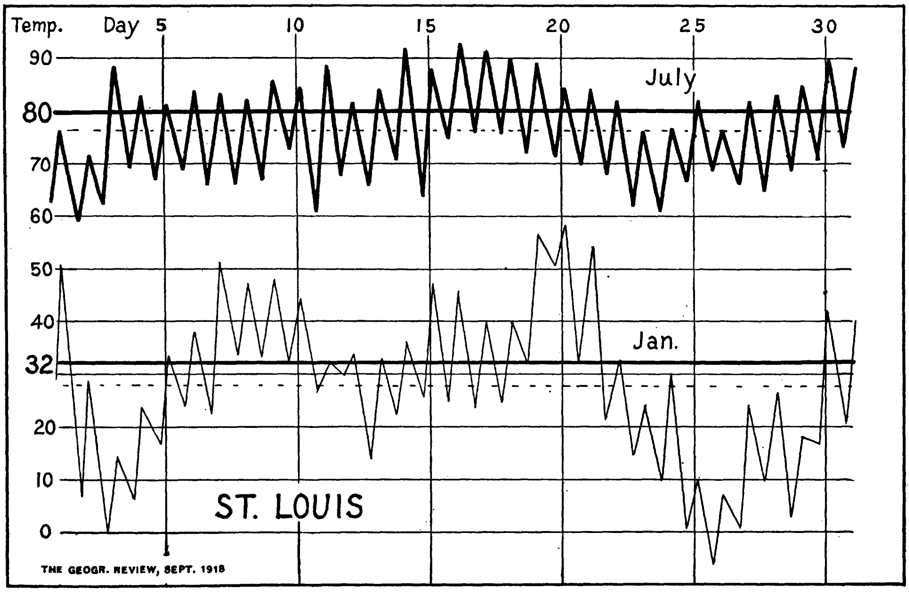

Fig. 27 (year: 1904)

July: mean: 76°; range 16°; variability 3.2°; rainfall 3.1 ins.
January: " 28°; " 16°; " 10.4°; " 3.2 ins.

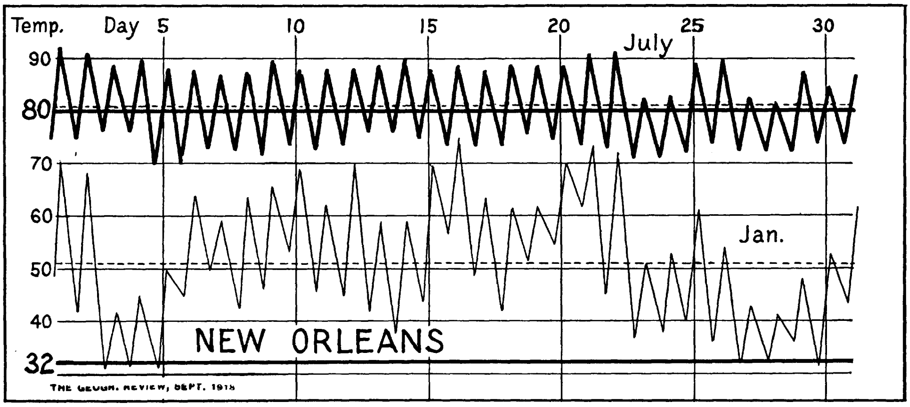

Fig. 28 (year: 1904)

July: mean: 81°; range 14°; variability 1.5°; rainfall 8.30 ins.
January: " 51°; " 17°; " 7.0°; " 1.50 ins.

In 1904 January had five days that differed more than 20° from the mean of the month, fifteen that differed more than 10°, and twelve that differed more than 5°. For the eastern United States it is the characteristic temperate zone weather, with somewhat variable summer temperatures and a winter of closely following mild and cold spells that are distinctly in contrast.

New Orleans

For the southern part of the eastern United States New Orleans is a rather extreme example (Fig. 28). The summer heats are considerable but of almost tropical steadiness, much like the temperatures at Havana though about a degree cooler. The winter is mild in temperature but strongly variable. Variabilities for New Orleans are 1.5° and 7°. No July day varies more than 4° from the mean of the month, but in January nine days varied by more than 10°.

Factors Influencing Daily Temperature Range

Some mention has been made in the comments on these diagrams of the varying daily range of temperature. It appears to be dependent to a great degree on the amount of clear sky, which in turn is limited by the rainfall, and this implies clouds. Again position near to the sea or remote from it matters a great deal. The places of least daily range of temperature in all America are:

	Daily Range	
	Summer	*Winter*
Laurie Island (in far South Atlantic)	3.5°	13°
Victoria, B. C. (Pacific coast of North America)	14°	5°
Key West (Gulf of Mexico at southwest tip of Florida)	10°	10°
Mollendo (Pacific coast of Peru)	11°	10°
Prospect, Bermuda (island in North Atlantic)	10°	11°

About ten degrees' difference between day and night characterizes these places. Ocean waters lend themselves to a uniform temperature, as they are slow to heat up and to cool off. Moreover the oceanic situation favors clouds and rain, as it is mainly from the ocean surface that the water is evaporated. Victoria, B. C., has about seven times as much rain in February as in July; so that there are many clouds, and the daily range of temperature in that season is only 5°. Laurie Island may have reversed conditions.

Next in order of daily temperature range come the nine seaports:

	Daily Range	
	Summer	*Winter*
New York	13°	12°
San Francisco	14°	11°
Buenos Aires	18°	10°
Havana	16°	14°
New Orleans	14°	17°
St. Johns, Nfd.	19°	12°
St. Louis	16°	16°
Panama	16°	19°
Marshfield, Ore.	20°	15°

Perhaps it would have been better to have called them eight seaports and St. Louis. They have been arranged in order of the magnitude of the daily ranges, and St. Louis happens to fall among them. It appears to be an exception to a rule. The situation of these places by the sea makes them prone to cloudiness, which prevents the heating up by day and the cooling off by night that results in a diminished daily range of temperature.

The remaining thirteen places are all from continental interiors, regions that are arid, which means that clouds are scarce. Clear skies result in strong daily alternations of temperature. Six of the thirteen places are in the tropics and seven in the temperate zone. Great range of temperature has no relation to zone but belongs to continental interiors, just as small range belongs to places situated near the sea.

	Daily Range	
	Summer	*Winter*
Dawson City	24°	15°
Toronto	22°	16°
16 de Octubre	25°	15°
Salt Lake City ..	26°	16°
Winnipeg	26°	20°
La Joya	22°	28°
Cuzco	25°	27°

	Daily Range	
	Summer	*Winter*
Toluca	30°	23°
Santa Ana	24°	29°
Denver	27°	27°
Arequipa	23°	36°
Phoenix	29°	31°
Vincocaya	26°	43°

This feature of the magnitude of the daily range crosses the variability of the daily temperature, which is very low in the tropics, on shore, and in the interiors alike in the miscalled temperate zone. The combination of daily ranges and variabilities comes to expression in the graphs that have been used to indicate the facts of actual temperatures throughout the length of America.